Metal-rich T-dwarfs in the Hyades cluster

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Abstract. We present the results of a search for brown dwarfs (BDs) and very low mass (VLM) stars in the 625 Myr-old, metal-rich ([Fe/H]=0.14) Hyades cluster. We performed a deep (I=23, z=22.5) photometric survey over 16 deg^2 around the cluster center. We report the discovery of the first 2 BDs in the Hyades cluster, with a spectral type T1 and T2, respectively. Their optical and near-IR photometry, as well as their proper motion, are consistent with them being cluster members. According to models, their mass is about 50 Jupiter masses at an age of 625 Myr. We also report the discovery of 3 new very low mass stellar members and confirm the membership of 15 others.

THE HYADES CLUSTER

The Hyades (Melotte 25, α_{2000}=04^{h}26^{m}54^s, δ_{2000}=+15^{o}52$'$; l=180.05^o, b=-22.40^o) is one of the richest open clusters and the closest to the Sun. Perryman et al. (2008) derived its main structural and kinematical properties based on Hipparcos measurements : a distance of 46.3$\pm$0.27 pc, an age of 625$\pm$50 Myr, a metallicity [Fe/H] of 0.14$\pm$0.05, a present-day total mass of about 400 M$_\odot$, a tidal radius of 10.3 pc, a core radius of 2.5-3.0 pc and negligible extinction on the line of sight. The large proper motion of the cluster ($\mu \simeq$100 mas yr^{-1}) can easily be measured from imaging surveys over a timeframe of only a few years, which helps in assessing cluster's membership.

THE CFHT SURVEY

Wide-field optical images were obtained in the I and z bands with the CFHT 12K camera, a mosaic of 12 CCD arrays with a pixel size of 0.21$''$ which provides a FOV of 42$'\times$28$'$. The survey consists of 53 mosaic fields covering a total of 16 square degrees. It extends symmetrically around the cluster's center, along a 4 deg-wide stripe of constant galactic latitude, and up to 3 degrees away from the cluster center in galactic longitude. The survey is at least 90% complete down to I$\sim$23.0 and z$\sim$22.5, a limit which varies only slightly with seeing conditions (0.6-0.8 arcsec).

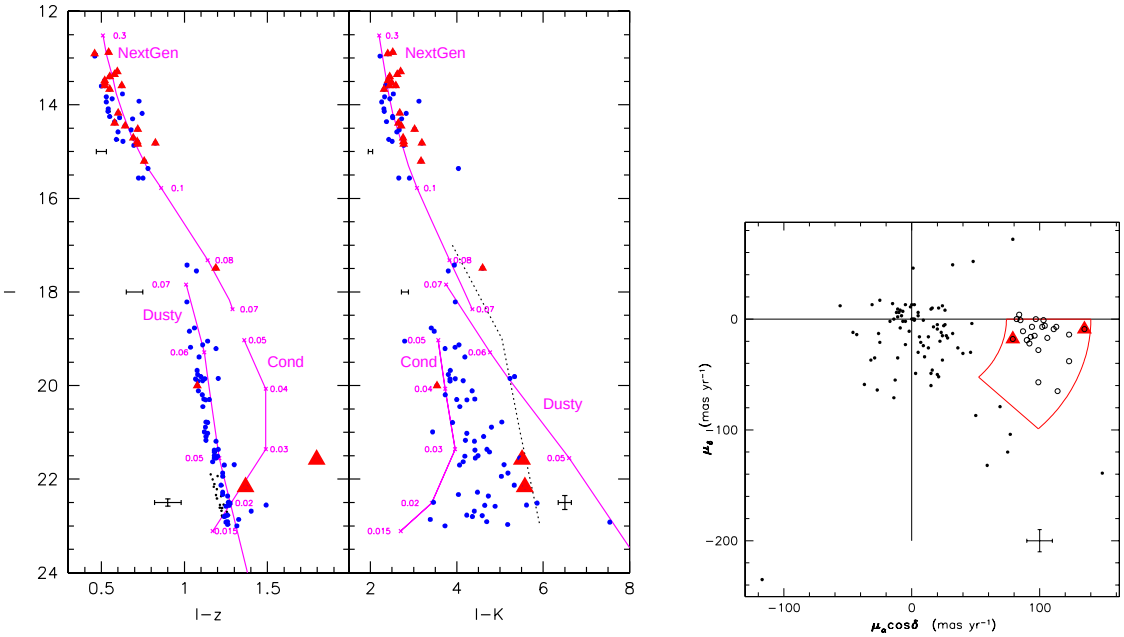

FIGURE 1. **Left :** (I, I-z) and (I, I-K) CMDs of optically selected candidated followed up with CFHT IR in the K-band. Small dots : 17 optically selected candidates without follow up IR photometry. Large dots : optically selected candidates whose proper motion is inconsistent with Hyades membership (cf. right panel). Triangles : candidates whose proper motion is consistent with Hyades membership. The stellar/substellar boundary occurs at I$\simeq$17.8 mag. The 2 most promising substellar cluster candidates are shown by large triangles. NextGen (0.07-0.3 $M_\odot$), Dusty (0.04-0.07 $M_\odot$), and Cond (0.015-0.05 $M_\odot$) 600 Myr isochrones are shown and labelled with mass (Baraffe et al. 1998; Chabrier et al. 2000). In the (I, I-K) CMD, the dotted line indicates the locus of M8-T5 field dwarfs (from Dahn et al. 2002). The rms photometric error is shown as bars. **Right :** Proper motion vector diagram for 107 optically selected candidates followed up in the K-band (see text). The expected proper motion for Hyades members is shown by the (red) box (Bryja et al. 2004). Within these boundaries, 23 optically selected candidates (empty circles) are found to share the proper motion of the cluster, including 2 BDs (large triangles). Typical rms errors on the ppm measurements are shown by a cross.

CANDIDATE MEMBER SELECTION

PSF photometry was performed on the I and z-band images with a modified version of SExtractor (Bertin & Arnouts 1996) from a PSF model computed with the PSFEx software. The (I, I-z) color magnitude diagram (CMD) is shown in Fig 1. A total of 125 possible Hyades members were selected in this CMD from their location relative to model isochrones. Follow up K-band imaging was obtained for 108 of the 125 optically selected candidate members using the 1k$\times$1k CFHT IR camera. The (I, I-K) CMD for the 108 candidates followed up in the K-band is shown in Fig 1. In addition, the proper motion of optically selected Hyades candidates was computed from pairs of optical (I, z) and infrared (K) images obtained 2 or 3 years apart. The proper motion vector diagram of 107 optically selected Hyades candidate members is shown in Figure 1.

TABLE 1. The lowest mass Hyades members : photometry and proper motion.

CFHT-Hy-#	RA(2000)	Dec(2000)	I	I-z	I-K	$\mu_{\alpha\cos\delta}$ ($mas.yr^{-1}$)	μ_δ	Mass ($M_\odot$)
CFHT-Hy-19	4 17 24.8	16 34 36	17.49	1.18	4.59	99	-28	0.08
CFHT-Hy-20	4 30 38.7	13 09 57	21.58	1.79	5.50	135	-9	0.05
CFHT-Hy-21	4 29 22.7	15 35 29	22.16	1.36	5.57	79	-18	0.05

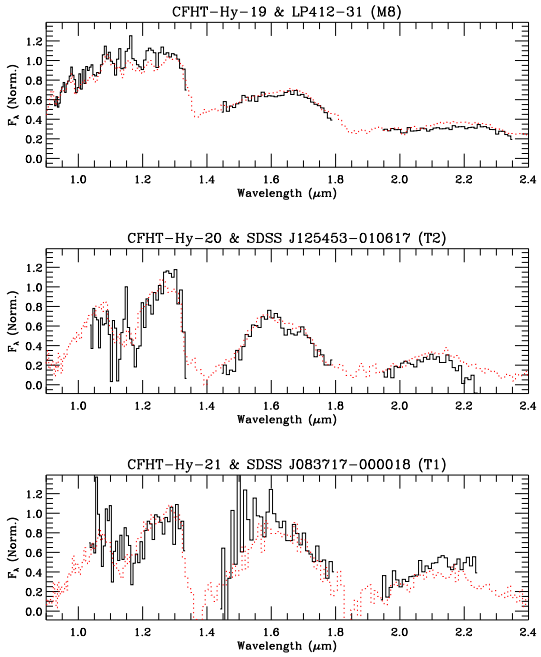

FIGURE 2. Near-infrared Amici low resolution spectra of CFHT-Hy-19, 20 and 21 (solid lines from top to bottom). In each panel we also show the closest matching field dwarf spectrum (dotted line) from the low resolution Amici spectral library (Testi et al. 2001; Testi 2004).

BROWN DWARFS IN THE HYADES CLUSTER

Based on photometry and astrometry, we eventually identified 20 candidates which consistently qualify as probable Hyades members on the basis of their optical photometry, (I-K) color and proper motion. Of these, 15 were already listed as possible or probable Hyades members in Prosser & Stauffer's Open Cluster Database. The remaining 5 probable members we report here are new. They include 3 low mass stars ($\sim$0.14 $M_\odot$) and 2 objects well within the substellar regime ($\sim$0.050 $M_\odot$).

Our survey thus identifies the first 2 Hyades BD candidates (CFHT-Hy-20, 21) as well as a previously detected very low mass star (CFHT-Hy-19) close to the stellar-substellar boundary, that had originally been considered as a non-member by Gizis et al. (1999).

The properties of these lowest mass members are listed in Table 1. The 2 BDs are well within the substellar domain with an estimated mass of about 50 Jupiter masses while the lowest mass star has an estimated mass around 0.08 $M_{\odot}$. Low resolution infrared spectra were obtained for these 3 objects using TNG/NICS and are shown in Figure 2. Fitting the observed spectra with those of template field dwarfs observed with the same instrument, we derive a spectral type of M8, T2 and T1 for CFHT-Hy-19, 20 and 21, respectively.

The 2 T-dwarfs we report here are strong candidate Hyades members based on their consistent photometry and proper motion. Nevertheless, we proceed in estimating the probability that they could be unrelated field T dwarfs projected onto the Hyades cluster. From the combination of the 2MASS and SDSS DR1 surveys, Metchev et al. (2008) derived an upper limit of 0.9×10^{-3} pc^{-3} on the space density of T0-T2.5 dwarfs in the solar neighborhood. Combining the area of our survey with the range of distances for possible field contaminants, the corresponding volume is 65 pc^3. We thus expect $\leq$0.06 early field T dwarf to contaminate our survey. This estimate further strengthens the likelihood that the 2 candidates we report here are indeed the first BDs and the lowest mass members of the Hyades cluster known to date.

CONCLUSION

Our survey is complete in the mass range from less than 50 Jupiter masses up to 0.20 $M_{\odot}$. In this mass range, we identified 18 very low mass stars, down to the stellar-substellar limit, as well as 2 brown dwarfs with a spectral type T1 and T2. These are the first T-dwarfs identified in the Hyades cluster at an age of 625 Myr, and also the only known instances of metal-rich ([Fe/H]=0.14) methane dwarfs. A full account of these results is given in Bouvier et al. (2008)[1]. Additional spectroscopy is planned on Gemini during the fall of 2008 in order to investigate the spectral characteristics of metal-rich T-dwarfs in more detail and confront them with model predictions.

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[1] More recently, Hogan et al. (2008) reported the discovery of 12 L-dwarfs in the cluster.

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